955 L'Enfant Plaza North, S.W.

Washington, D. C. 20024

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September 30, 1971

to:

Distribution

from:

E. W. Radany

subject:

April 30, 12:30 EST SL-1 Launch; U.S. EREP Pass Characteristics and Preliminary Estimate of Cloud Cover Effects - Case 610

ABSTRACT

Potential daylight EREP passes over the United States were identified by means of simulated Skylab missions based on an April 30, 12:30 EST launch of SL-1. Candidate passes were required to simultaneously satisfy specific criteria regarding duration, sun elevation at points along the ground track, the magnitude of beta (the angle of the solar vector to the orbit plane), and crew time-line interference. three such potential EREP passes were counted during the SL-2 mission, ninety-eight during the SL-3 mission, and thirty during the SL-4 mission.

The duration and the local times of occurrence of the individual passes are presented graphically for each mis-The average pass characteristics (i.e., duration and local time of occurrence) over five-day intervals are used in conjunction with nationwide averaged cloud statistics to esta mate the effects of cloud cover. The estimate of the cloud cover effects is presented in terms of "effective pass dur tion", defined as the product of the cloud-free duration a the probability that the ground track cloud cover is less The effective pass durations during the SL-2 mi sion are generally about 35% of the corresponding cloud-free pass durations; about 45% during the SL-3 mission; and about 38% for the SL-4 passes which occur in October and November, and about 30% for the SL-4 passes which occur in December. The effective pass durations which prevail during the August 23 - September 15 period of the SL-3 mission exceed those attained during either of the other two missions. Summarizing,

a total of about 230 minutes of well-lighted U.S.A. coverage

with less than 30% cloud cover can be expected to be available during the SL-2 mission, about 327 minutes during the SL-3 mission, and about 75 minutes during the SL-4 mission. the individual missions, therefore, SL-3 is expected to be

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most productive.



This investigation of EREP pass characteristics and the associated preliminary estimate of cloud cover effects suggests that serious consideration should be given to redistributing the presently planned (9/18/18) pass allocation so as to place heavier emphasis on EREP investigations during the SL-3 mission



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MEMORANDUM FOR FILE

Introduction

The S-190 Multi-Spectral Photographic Facility will either be the prime instrument or a supporting sensor in about 76% of the earth resources investigations currently under consideration by NASA; reference 1. This study was limited to consideration only of daylight passes, simply because of the paramount importance of photography to the majority of EREP investigations. It of course is recognized that night-time passes employing certain of the other EREP sensors may also be desired.

Aside from adequate lighting of the ground track for a sufficient duration, the success of performing photography will be influenced to a large extent by the distribution of clouds over the ground track. The cloud cover over the ground track during a given pass in turn will be determined by the season, the particular region being overflown, and the local (i.e., solar) time at that region; Reference 2. This study was further restricted to consideration only of passes over the U.S., merely in order to bound the problem. Other areas of the world (e.g., Australia, Brazil), however, certainly will be investigated.

The characteristics of the potential daylight EREP passes over the United States which occur during the three Skylab missions of the baseline sequence (Reference 3) are presented in this memorandum. The candidate EREP passes were required to simultaneously satisfy specific criteria regarding: their occurrence relative to the crew time lines; the minimum duration over which the sun elevation angle at points on the ground track exceeded a prescribed value; and, the maximum allowable magnitude of beta, the angle of the solar vector to



the orbit plane. Cloud cover, however, was not one of the pass selection criteria. The characteristics of the potential EREP passes are then used in conjunction with available cloud statistics in order to estimate the effects of cloud cover on the probability of successfully performing photography.

Pass Selection Criteria

Skylab missions based on the launch parameters (tabulated below) which will be used by MSC/MPAD for generating a revised Preliminary Reference Trajectory and Flight Plan were "flown" via computer simulation in order to identify potential EREP passes over the U.S.

Mission	Nominal Launch Liftoff on Date (1973) Time (EST)		Recovery (Local Standard Time)				
SL-1	April 30	12:30 pm					
SL-2	May 1	Noon	9:00 am - Atlantic				
SL-3	July 24	2:30 am	11:30 am - Atlantic				
SL-4	October 28	11:15 am	Noon - Pacific				

For the purpose of the computer simulations, the U.S. was represented as a (spherical) rectangle bounded on the south by 24° north latitude and on the north by 50° north latitude, and bounded on the east by 74.5° west longitude and on the west by 124° west longitude. In order to qualify as a potential EREP pass, an overflight of the U.S. was required to simultaneously satisfy the following criteria:

- 1. The duration of the portion of a pass for which the sun elevation angle at points on the ground track is greater than a prescribed minimum value must exceed one minute. The minumum acceptable sun elevation angle was assumed to be 30° in "summer" (i.e., during the SL-2 and SL-3 missions when the sun's declination is northerly), and was assumed to be 20° in "winter" (i.e., during the SL-4 mission when the sun's declination is southerly); Reference 4.
- 2. Beta (the angle of the solar vector to the orbit plane) must be less than 50°.
- 3. The pass must occur either between 6:00 and 10:30 EST, or between 12:00 and 16:00 EST on any day.



The first criterion embodies two distinct considerations. One minute was arbitrarily selected as a duration limit below which the acquisition of a sufficient quantity of data to make it worthwhile to re-orient the cluster to z-local vertical appeared unlikely. The specification of minimum acceptable sun elevation angles at points along the ground track ensures adequate lighting for performing S-190 photography. It should be noted that only that portion of a pass for which the minimum sun elevation constraint was satisfied while over the U.S. was counted when tabulating pass durations. The second criterion reflects the flight rule (based on thermal and electrical power considerations) prohibiting the cluster from entering the zlocal vertical attitude when beta exceeds 50°. The third criterion conforms with the crews timelines developed in Reference Since the crew timelines are tentative, this criterion was not considered to be inviolable. Consequently, occasional passes which started or ended within five minutes of one of the stated time boundaries were accepted as candidate EREP passes; e.g., a pass which started at 11:56 EST and ended at 12:07 EST would be counted as an eleven minute pass. For the purpose of this investigation it was also assumed that the first and last days of each mission would be devoted to Workshop activation and shutdown operations, respectively. Potential EREP passes occurring on either the first or last days of each mission accordingly were omitted from the tabulations. This last assumption is somewhat optimistic with regard to the number of potential passes counted since probably two days, rather than only one, will be unavailable for experimentation at each end of the mission, nor have EVA days been excluded. more, although all the potential EREP passes are identified here, it should be recognized that during the actual mission the EREP passes cannot be chosen arbitrarily. This is because there are yet other (flight) rules regarding the allowable frequency of entry into Z-LV, number of consecutive Z-LV orbits, etc.

Potential EREP Pass Characteristics

Circles and squares, respectively, are used to denote ascending and descending passes in the accompanying figures. Ascending passes are those during which the spacecraft crosses the region of interest while traveling northerly; the ground tracks of ascending passes accordingly extend in a generally southwest-to-northeast direction. Descending passes are those during which the region of interest is crossed by the spacecraft while traveling southerly; the ground tracks of descending passes extend in a generally northwest-to-southeast direction. Portions of a few of the high latitude ascending pass ground tracks shown later (in Figure 12) are



actually descending, and conversly for a few of the descending pass ground tracks (in Figure 13). For simplicity these cases were resolved by categorizing passes as "ascending" if the latitude of the eastern end point of the pass was farther north than that of the western end point, and vice versa for descending passes.

Figures 1, 3, and 5 present the durations of the candidate EREP passes which occur during the SL-2, SL-3, and SL-4 missions, respectively. Figures 2, 4, and 6 present the associated range of local time (dependent on the longitudinal extent of each pass) spanned by each pass. The mean local time of each pass is also indicated in these figures. mean time of a pass is simply the average of the local times prevailing at the end points of a pass, and is not weighted by the portions of a pass spent over different time zones. The distinction between EST, the time frame on which the astronauts live (the basis for the third pass-selection criterion), and the local solar time (LST) actually prevailing at the region being overflown should be noted. Data for the 20° and 30° sun elevation angle constraints are presented in Figures 5 and 6 in order to show the effect of relaxing this constraint during the SL-4 mission.

The potential EREP passes are numbered sequentially in order of their occurrence in Figures 1 through 6. The data in each of these figures are plotted with respect to a dual abscissa, one indicating pass number, and the other indicating calendar date of occurrence. Because the data are plotted in this manner, the lengths of the individual horizontal strokes of the "date" abscissa are indicative of the number of passes occurring on a particular date. The average duration and the average local time of occurrence of all ascending (or descending) passes which occur during a mission are represented by centerlines (-.-). The pass characteristics averaged over (generally) five-day intervals are denoted by dashed lines (---). days is a somewhat natural cycle since the ground tracks nearly repeat every five days.) Average pass characteristics over other than five-day intervals are sometimes presented, simply because the number of consecutive days in a mission on which either ascending or descending passes will occur is not necessarily a multiple of five. The characteristics of the U.S. EREP passes revealed in figures 1 through 6 are discussed below.

The EREP passes occurring during the first five days of the SL-2 mission will all be ascending passes. Both ascending and descending passes will occur between May 7 and 20. After May 20, and until the end of the mission, all



passes will be descending. With the exception of only one day early in the mission and two days at the end, at least three potential EREP passes will occur on every day of the SL-2 mission. A maximum of five potential passes occur on May 16, and four passes usually occur on each of the seven days before and after May 16. A total of 93 potential EREP passes (42 ascending and 51 descending) were found to occur during the entire SL-2 mission. It is presently planned that nine EREP passes will actually be performed during the SL-2 mission; i.e., about one out of every ten potential passes will actually be used.

Descending EREP passes will occur during the first six days of the SL-3 mission. This will then be followed by a 2-1/2 week period during which no passes will occur at all. This is followed by a three-week period of exclusively ascending passes. The passes will occur with a frequency of only one per day during the first five days of this period, then increasing to two or three a day for the next ten days. scending passes will begin to occur on about September 1. Both ascending and descending passes will occur during the period from September 1 through September 13, with a total of three or four passes occurring daily. Only descending passes will occur after September 13. A total of 98 potential EREP passes (55 ascending and 43 descending) were found to occur during the entire SL-3 mission. It is presently planned that 18 EREP passes will actually be performed during the SL-3 mission; i.e., about one out of every five potential opportunities will be used.

The picture for the SL-4 mission changes quite drastically. Ascending passes will occur during the first two days of the mission. This will be followed by a period of almost two weeks during which no passes will occur. scending passes will occur during a ten-day period in November, at frequencies varying between one and three per day. A one-month period wherein again no passes occur begins on November 27. Ascending passes then will occur at frequencies of one or two per day during a three-day period near the end of the third week in December. The simulation indicated only 30 potential EREP passes (9 ascending and 21 descending) to occur during the entire SL-4 mission. Since 18 EREP passes are also planned to be performed during this mission (i.e., on the average, using better than every other available pass opportunity), not very many pass opportunities could be deferred without possibly jeopardizing the completion of the experiment objectives.



Comparing the data for twenty degree and thirty degree sun elevation angles in Figure 5 indicates that, as expected, relaxing the sun elevation constraint (in general) increased the pass duration. It is surprising to note, however, that no new passes became acceptable. There are still only 30 in the entire 56 day period. Figure 6 shows that the average LST for the ascending passes is about a half-hour later with the relaxed sun elevation constraint; i.e., relaxing the sun elevation constraint generally extends the passes eastward. Relaxing the sun elevation constraint moves the descending pass average LST about 15 minutes earlier, i.e., the descending passes are extended westerly by relaxing the constraint.

Figures 7 through 11 present the data of Figures 1 through 6 replotted in "LST/duration-space;" the explicit indication of the dates of pass occurrence, however, is lost in the process. The same symbolism for indicating ascending and descending passes is used again, and the passes are numbered as before. Each figure is sub-divided into the (generally) five-day intervals of the previous figures, and the mean LST and duration of the "average" pass during each interval is indicated by a target ().

These figures show (more clearly than the preceding group) that the average ascending or descending passes occur at successively earlier local times as any of the three missions progress in time. This observation applies to the averages for five-day intervals that are time-wise contiguous but excludes the short (i.e., two passes over two days) September 12-13 interval of ascending passes near the end of the SL-3 mission. The average pass durations do not exhibit any similar, consistent trends.

The use of the previously presented data in estimating the effects of cloud cover on EREP investigations is discussed below.

Cloud Cover Effects

Reference 2 is deemed to be the best compendium of worldwide cloud statistics currently available. (An extension of reference 2 which incorporates satellite-acquired data was recently completed by the same authors but has not been published in its entirety yet.) Cloud cover data are given in reference 2 for 29 nominally homogeneous climatological regions chosen to represent the earth; most of these regions are repeated two or more times over the globe. Portions of twelve of these 29 climatological regions appear in the rectangular representation of the U.S. employed in the EREP pass simulations. The diurnal and seasonal variations of cloud cover



peculiar to these particular twelve regions, therefore, can substantially affect the probable success of EREP photography. How the potential EREP passes are distributed with respect to the various cloud regions thus is the next question of interest.

Figure 12 shows the ground tracks of the potential ascending EREP passes which occur during the SL-2 mission; the division of the rectangular U.S. into the 12 pertinent climatological regions is also shown. The ground tracks of the passes appear to be rather uniformly distributed with respect to the various cloud regions. The ground tracks of the descending passes during the SL-2 mission, as well as those of the passes occurring during the other two missions exhibit similar uniformity. (Figures 123 through 125 of Reference 6, albeit for a prior set of launch parameters, exhibit similar uniformity of the ground track distributions.)

The uniformity of the ground track distributions in relation to the cloud regions shown in Figure 12 suggests than an estimate of cloud cover effects based on a nationwide average of the cloud statistics for the entire U.S. could be calculated quite simply. The nationwide average could be taken to be the weighted sum of the statistics for the 12 climatological regions which appear in the rectangular representation of the U.S., the weighting factor for each region simply being its percentage contribution to the total area of the rectangle. It is recognized that defining the weighting factors strictly geometrically does not account for the differences in time spent over various latitudes by a spacecraft in an inclined orbit. This deficiency is at least partially offset by the fact that (for a 50° inclination orbit) the difference in the time spent over various latitudes is not very significant for latitudes less than about 46°. Fortunately, the majority of interesting ground sites seem to be distributed at more southerly latitudes. The weighting factors for the 12 regions defined in the foregoing manner (and based on a spherical surface) are given in Table I.

The weighted average unconditional* probabilities that the cloud cover is less than 30% are presented in Figure

^{*}The consideration of spatial and/or temporal conditional cloud statistics is presently thought to require the application of Monte Carlo techniques. This is a "second generation" study which may be the topic of a subsequent memorandum.



13 versus local time for the months of the year when potential EREP passes occur during the three missions. The data presented in Figure 13 were calculated by applying the weighting factors of Table I to the applicable cloud statistics of Reference 2. Reference 2 presents the unconditional probabilities of the occurrence of five categories of cloud cover on a monthly basis, with data being given at 3-hour intervals for each month. The five categories of cloud cover defined in Reference 2 vary from clear to 100% overcast. Thirty percent cloud cover was adopted as the basis for this study for two reasons. First, this appears to be an intuitively reasonable limit for performing photography. Second, the necessary data could be generated quite conveniently be merely summing the statistics for the Category 1 and Category 2 clouds of Reference 2.

As noted earlier, the success of most of the EREP investigations proposed by MSC will hinge on successfully performing primary or supporting photography. Axiomatically, the probability of successfully performing photography on a given pass must depend both on the duration of the pass having adequate lighting, and also on the probability of there being a sufficiently low level of cloud cover (i.e., ≤ 30% for this study) along the ground track. For the purpose of estimating the effects of cloud cover, then, an empirical "effective pass duration" was defined simply as the product of these two parameters. Figure 13 reveals that the diurnal variation in the cloud cover probabilities over the pertinent span of local time (i.e., between about 7:00 and 14:00) is at most about 12%. Figures 7 to 11 on the other hand often show variations in average pass duration (between contiguous 5-day intervals) of 45-50%. The variation in magnitude of the effective pass duration therefore will generally be determined by the variation in the cloud-free pass duration.

Effective pass durations were calculated according to the foregoing definition, multiplying the 5-day average pass durations (from Figures 7 to 11) by the cloud probabilities (Figure 13) at the appropriate mean local times and months. The calculated effective pass durations and the corresponding pass durations in the absence of clouds are presented in figures 14 through 16 for the three missions. Data for the two values of the sun elevation angle constraint are again presented (in Figure 16) for the SL-4 mission.

Figure 14 for the SL-2 mission indicates that the maximum average effective ascending pass duration prevails for the initial five-day interval of the mission, and then declines steadily for the intervals later in the mission. With the exception of this first five-day interval, the effective descending pass durations are longer than those for the ascending



passes; (this could have implications regarding EREP ground site selection). The effective descending pass duration remains at approximately a constant level of about three minutes for the entire period between May 7 and May 21, and then falls off by about 35% during the last five-day interval of descending passes. During the SL-2 mission the effective pass durations based on 30% cloud cover are generally about 35% of the corresponding cloud-free pass durations. A total of about 230 minutes (103 minutes for ascending passes and 127 minutes for descending passes) of well-lighted U.S.A. coverage with less than 30% cloud cover can be expected to be available during the SL-2 mission.

Figure 15 indicates that the shortest effective pass durations during the SL-3 mission prevail in the first fiveday interval (July 25-30). This initial interval is followed by a 2-1/2 week period at the start of August during which no passes occur at all. With the exception only of a five-day interval (August 18-22) of ascending passes when the occurrence of passes resumes, the effective pass durations (of both ascending and descending passes) during the latter half of the SL-3 mission are substantially longer than those in July. It is noteworthy that the effective pass durations which prevail during the August 23 - September 15 period are longer than those attained during either of the other two missions.

Scheduling EREP investigations to heavily utilize the ascending pass opportunities during the August 23 - September 7 period, and/or to utilize the descending passes during the September 1-15 period accordingly would appear to afford the best chances of success for the overall mission. observation certainly would not preclude the selection of specific individual passes during the July 25-30 or August 18-22 periods if this appeared desirable due to considerations of real-time cloud information, pass duration, and target area covered. During the SL-3 mission the effective pass durations based on 30% cloud cover are generally about 45% of the corresponding cloud-free pass durations. A total of about 327 minutes (186 minutes for ascending passes and 141 minutes for descending passes) of well lighted U.S.A. coverage with less than 30% cloud cover can be expected to be available during the SL-3 mission.

Figure 16 (a and b) indicates that maximum effective pass durations for the SL-4 mission prevail during the last two days of October, as soon as EREP opportunities become available. Regardless of the magnitude of the sun elevation constraint, the effective pass durations only get shorter after this initial interval. Due to the marked decline in effective



pass durations of both the ascending and the descending pass opportunities occurring in December, it would appear advantageous to attempt to perform all EREP activity prior to November 17. Here, again, opportune passes can of course be selected regardless of when they occur during the mission. During the SL-4 mission the effective pass durations based on 30% cloud cover are generally about 38% of the corresponding cloud-free pass durations for those passes which occur in October and November, and about 30% for those which occur in December. A total of about 75 minutes (23 minutes for ascending passes and 52 minutes for descending passes) of well-lighted U.S.A. coverage with less than 30% cloud cover can be expected to be available during the SL-4 mission.

Further Corroboration

The effective pass duration data presented in Figures 14 through 16 were calculated on the basis of pass durations and times of occurrence averaged over five-day intervals; i.e., the target points () of Figures 7-11. In Figures 14-16, however, large deviations of the durations of individual passes from the five-day averages are conspiciously frequent. The inclusion, particularly, of short duration passes in the five-day averages undermines the concept of basing the estimate of cloud cover effects on nationwide average cloud statistics. This is because (as reference to Figure 12 shows) short duration passes by their nature overfly only limited numbers of the climatological regions. In order, therefore, to enhance the credibility of the concept on which Figures 14-16 are based, a piecewise method of evaluating cloud effects was employed in order to corroborate two specific data points. The two points selected were for the ascending passes during the May 2-6 interval of the SL-2 mission, and for the descending passes during the November 17-22 interval of the SL-4 mission. The average pass duration for the May 2-6 interval is 9.4 minutes and with only one exception, all the individual passes (of which there are 14) are at least 6.7 minutes in duration. Intuitively, the concept of national average cloud statistics could be expected to be reasonably valid for this point. At the opposite extreme, the average pass duration for the November 17-22 interval is only 3.2 minutes, and the duration of two of the nine passes in the group is less than 2 minutes. The values cited are for 30° sun elevation angle constraint (Figure 11b). value of the sun elevation angle constraint was selected in preference to the 20° case because of its shorter average duration, thereby making this check point a more severe test of the national average cloud cover concept.



Figures 17a and 17b present the ground tracks of the 14 ascending passes which occur during the May 2-6 period; these ground tracks are distributed rather uniformly with respect to the 12 climatological regions. Figure 18 presents the ground tracks of the nine descending passes which occur during the November 17-22 interval. The beginning (i.e., the north end) of each of the ground tracks is controlled by the 30° sun elevation constraint, rather than by the northern or western boundaries of the U.S. As a result, two of the regions (8 and 11) which contribute most heavily to the nation-wide average cloud statistics are not overflown at all.

The ground track of the ninth ascending pass will be used to illustrate the mechanics of the piecewise cloudeffect evaluation procedure. The ground track is sub-divided in six segments, each crossing of a climatic region boundary or time zone boundary being considered as a breaking point. The duration of the spacecraft over each of the segments was approximated by prorating the total pass duration (from the digital computer simulations) by the ratio of the segment length to the total pass length (scaled from the figure). As illustrated in the following table, an effective duration was calculated for each segment of the pass by multiplying the duration over the segment by the appropriate probability read from Figure 19 for the region and local time peculiar to the segment; the effective duration for the pass is then the sum of the values for the six segments.

SEGMENT	A	<u>B</u>	<u>C</u>	D	E	F	∑(row)
Region Overflown	1	2	19	19	11	11	
Local Time	10.2	10.2	10.2	11.2	11.2	12.2	
Cloud Probability	.73	.55	.26	.26	.25	.23	
Duration, min.	1.20	2.42	0.71	0.93	2.90	1.85	10.0
Effective Duration, min.	087	1.34	0.19	0.24	0.74	0.42	3.79

Cloud cover thus will degrade the probability of successfully performing photography on the ninth pass by about 62%.

The foregoing procedure was applied to each of the 14 May 2-6 ground tracks and the resulting effective durations averaged; this value is plotted as a triangle in Figure 14. The same procedure was also applied to the nine November 17-22 ground tracks using the cloud statistics shown in Figure 20 (data for the regions not overflown are omitted); the resultant five-day average is plotted as a triangle in Figure 17b.



The values of effective pass duration calculated for both check points by the two different procedures agree to within 10%. The concept of nationwide cloud statistics seemingly, therefore, does not oversimplify the problem to the point of yielding grossly unrealistic results.

Conclusion

The preliminary estimate of cloud cover effects presented herein indicates that a total of about 230 minutes of well-lighted U.S.A. coverage with less than 30% cloud cover can be expected to be available during the SL-2 mission, about 327 minutes during the SL-3 mission, and about 75 minutes during the SL-4 mission. Based on the premise that these data appear to have a reasonable degree of validity, re-distributing the presently planned 9/18/18 EREP pass allocation between the three missions seems to be a matter which deserves serious consideration. Such a re-distribution should place heavier emphasis on EREP during the SL-3 mission.

Acknowledgment

The author is indebted to Mr. I. Hirsch for generating the simulated EREP pass data.

1025-EWR-bab

E. W. Radany



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TABLE I
Weighting Factor for Climatological Regions

Region	Weighting Factor
1	.045
2	.133
4	.090
5	.023
7	.052
8	.126
11	.266
12	.014
13	.014
18	.028
19	.177
20	.033

FIGURE 1 - EREP PASS DURATIONS; SL-2 MISSION

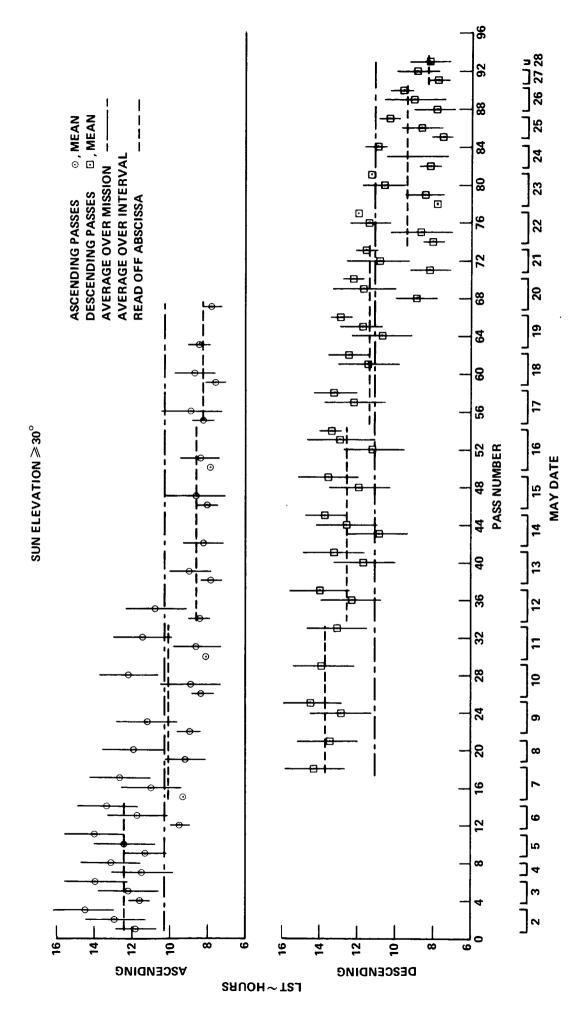


FIGURE 2 - LOCAL TIMES OF EREP PASS OCCURRENCE; SL-2 MISSION

FIGURE 3 - EREP PASS DURATIONS, SL-3 MISSION

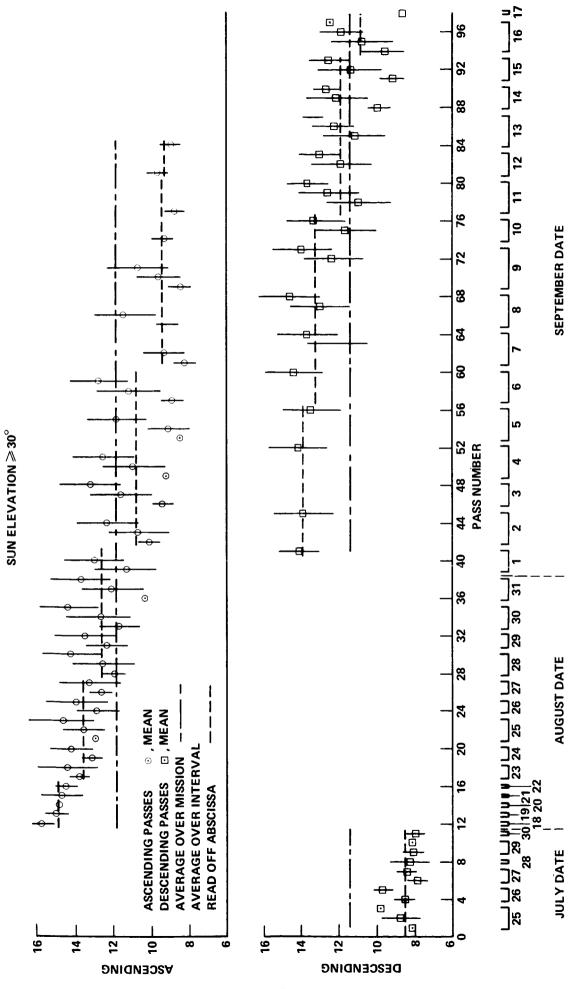
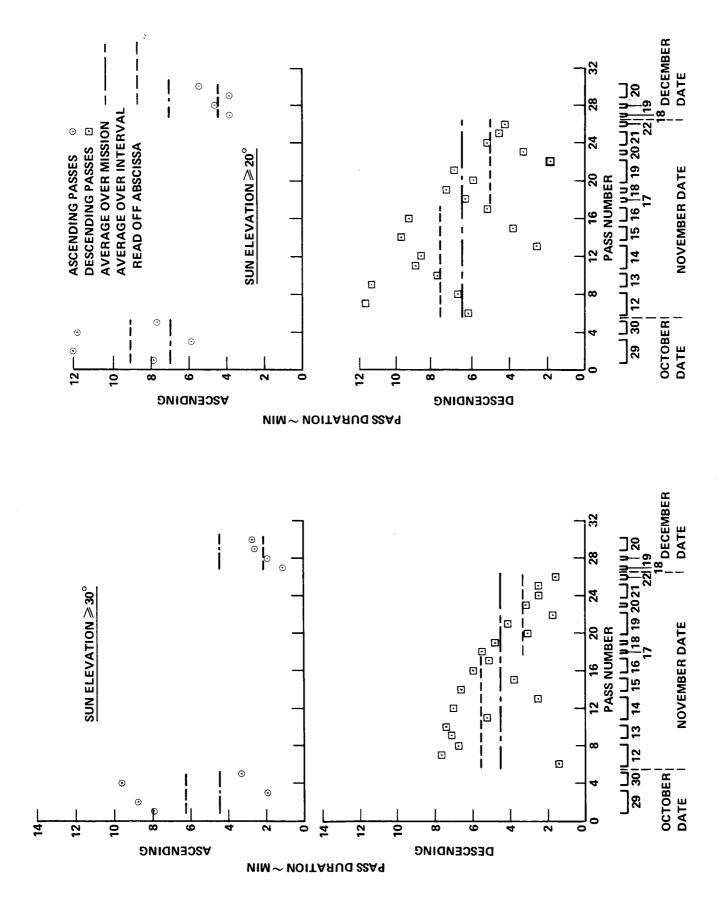
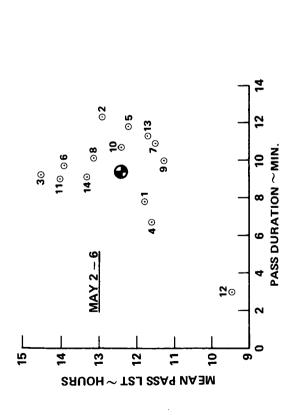


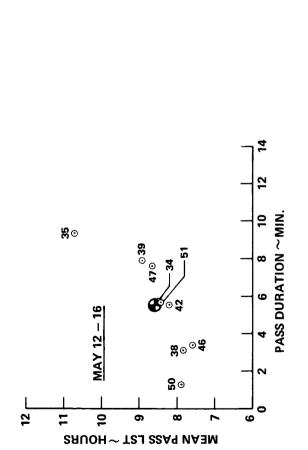
FIGURE 4 - LOCAL TIMES OF EREP PASS OCCURRENCE, SL-3 MISSION

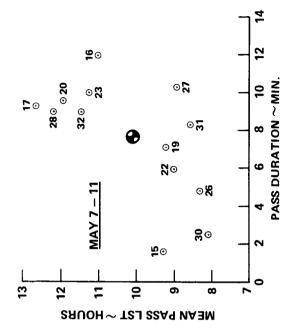


SRUOH~ TSJ

FIGURE 6 - LOCAL TIMES OF EREP PASS OCCURRENCE; SL-4 MISSION







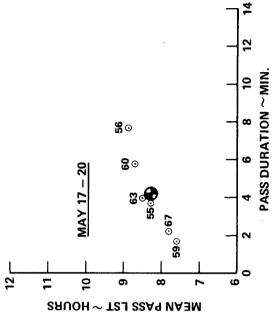
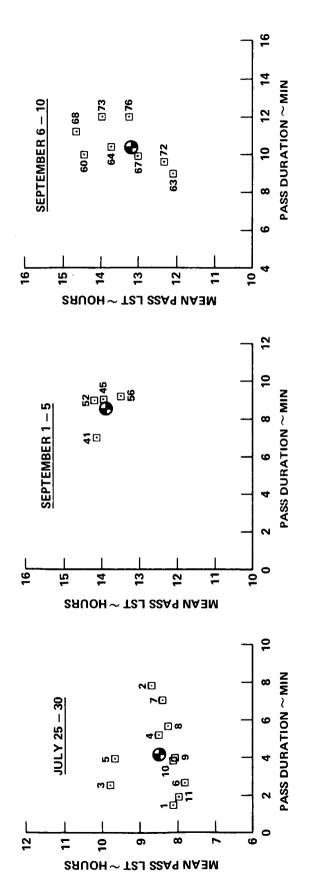


FIGURE 7 - ASCENDING PASS CHARACTERISTICS; SL-2 MISSION

Mean pass lst \sim hours

FIGURE 8 - DESCENDING PASS CHARACTERISTICS; SL-2 MISSION

FIGURE 9 - ASCENDING PASS CHARACTERISTICS; SL-3 MISSION



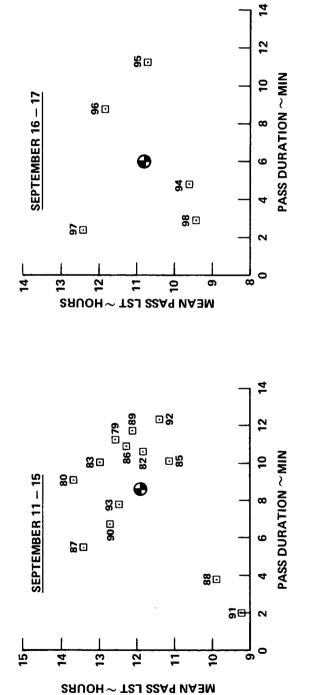


FIGURE 10 - DESCENDING PASS CHARACTERISTICS; SL-3 MISSION

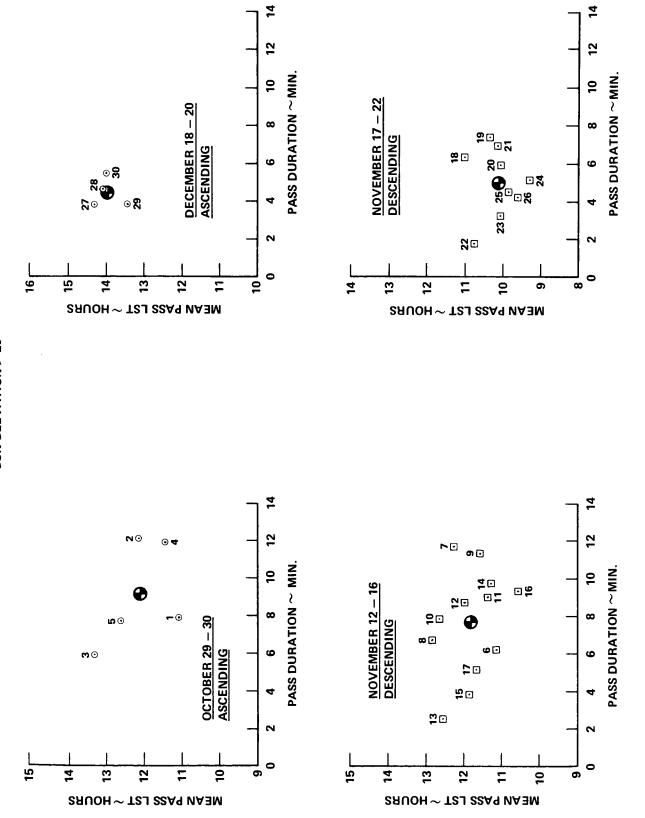
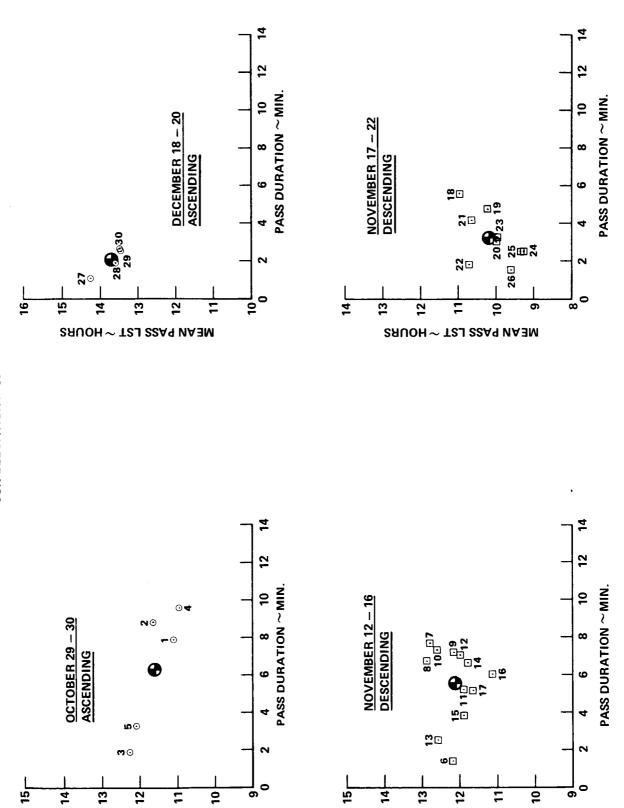


FIGURE 11a - ASCENDING & DESCENDING PASS CHARACTERISTICS; SL-4 MISSION

MEAN PASS LST \sim Hours



MEAN PASS LST \sim Hours

FIGURE 11b - ASCENDING & DESCENDING PASS CHARACTERISTICS; SL-4 MISSION

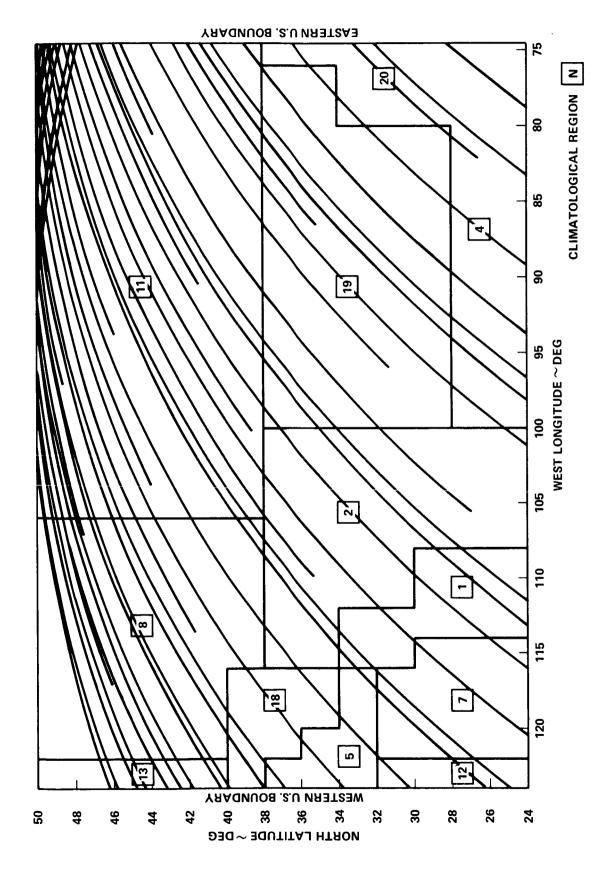


FIGURE 12 - GEOGRAPHIC DISTRIBUTION OF SL-2 MISSION ASCENDING PASSES

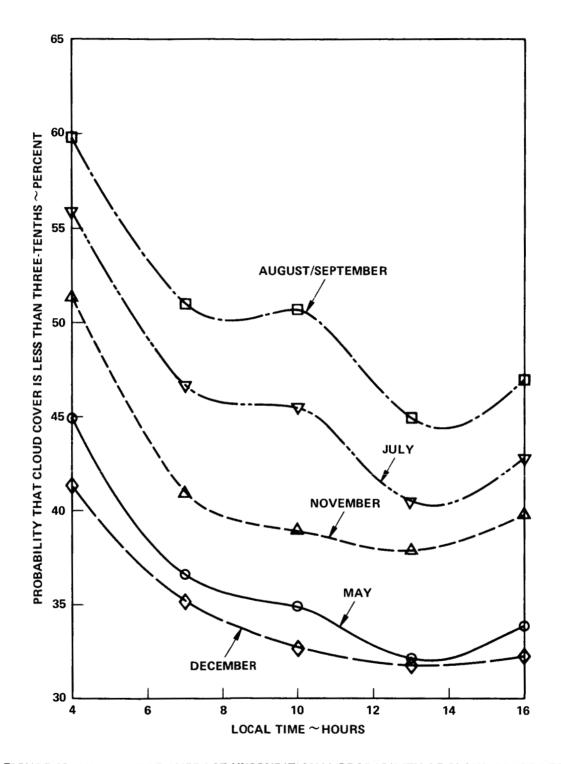


FIGURE 13 - NATION-WIDE AVERAGE UNCONDITIONAL PROBABILITY OF CLOUD COVER LESS THAN THREE-TENTHS

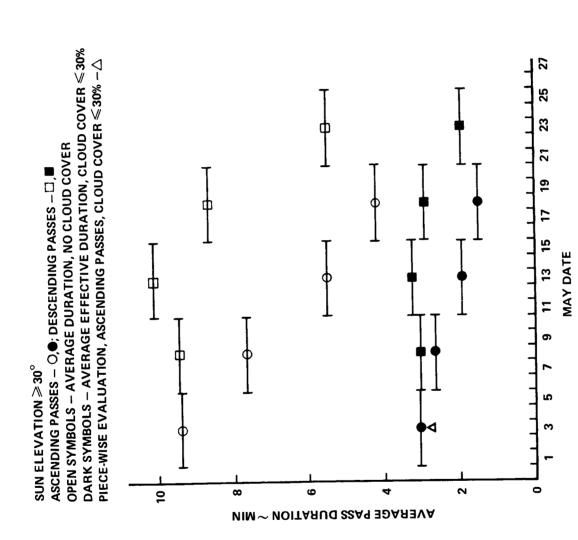


FIGURE 14 - AVERAGE PASS DURATION VS DATE; SL-2 MISSION

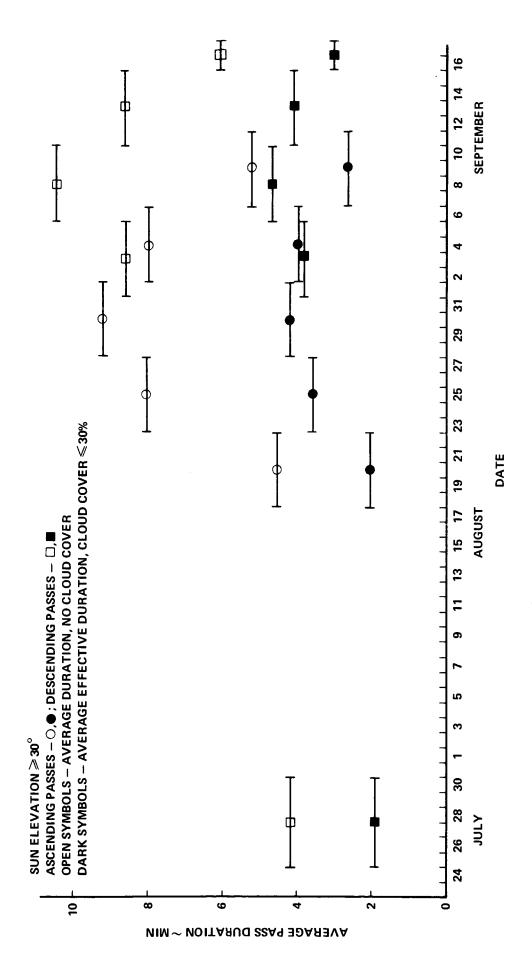


FIGURE 15 - AVERAGE PASS DURATION VS DATE; SL-3 MISSION

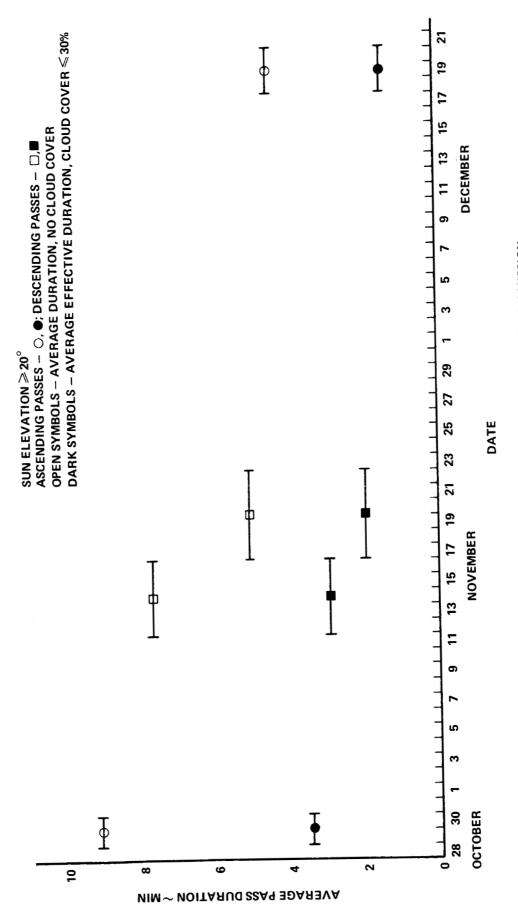
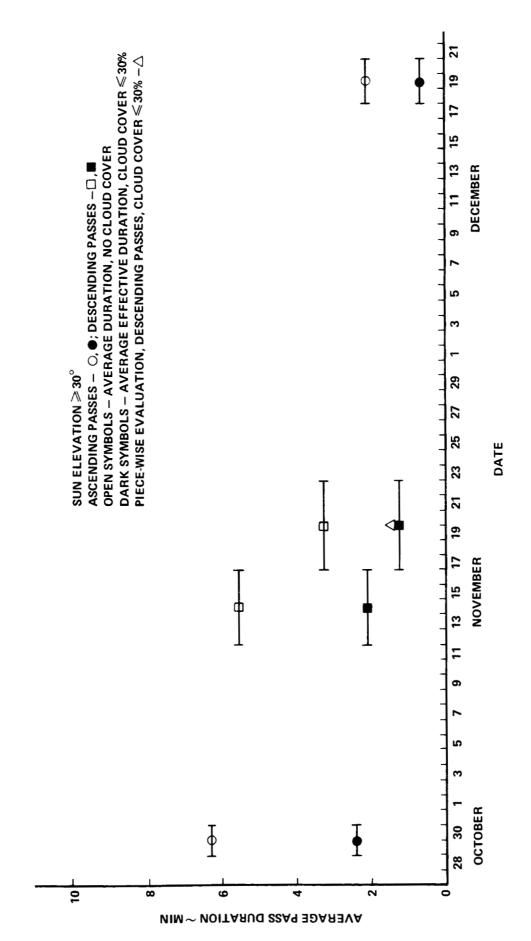


FIGURE 16a - AVERAGE PASS DURATION VS DATE; SL-4 MISSION



₹'

FIGURE 16b - AVERAGE PASS DURATION VS DATE; SL-4 MISSION

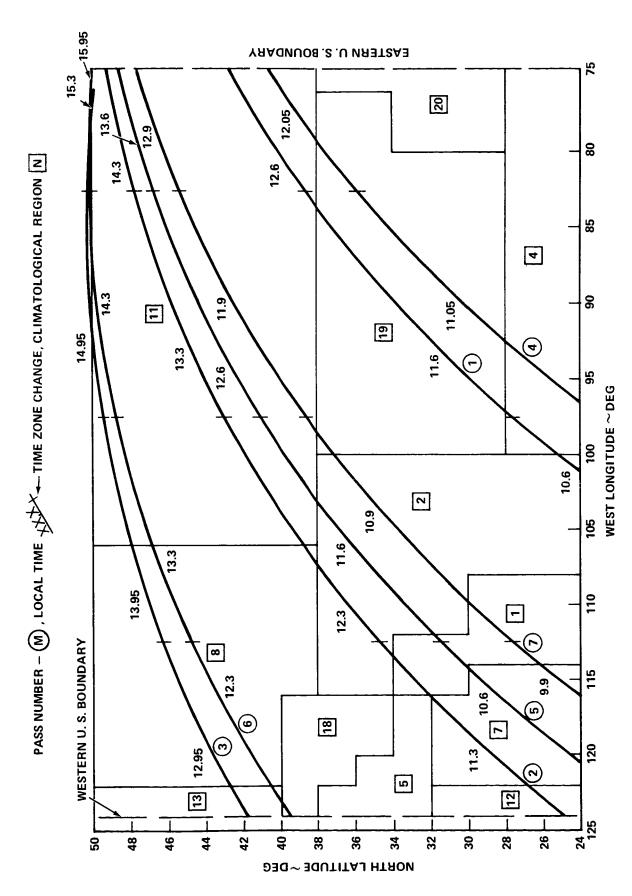


FIGURE 17a - ASCENDING PASS GROUND TRACKS, PASSES 1 - 7, MAY 2 - 6 INTERVAL OF SL-2 MISSION

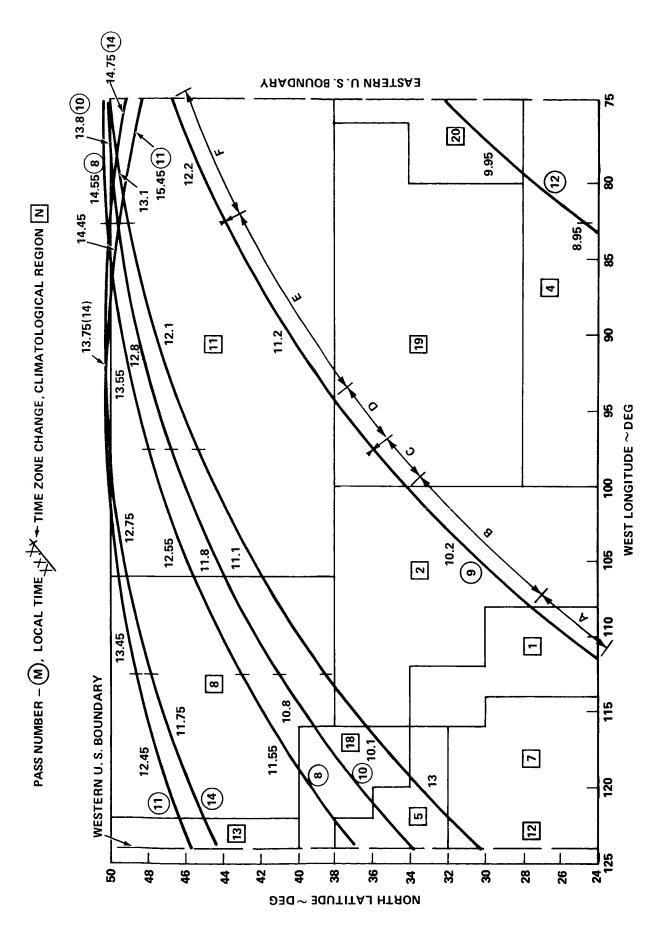


FIGURE 17b - ASCENDING PASS GROUND TRACKS, PASSES 8 -- 14, MAY 2 -- 6 INTERVAL OF SL-2 MISSION

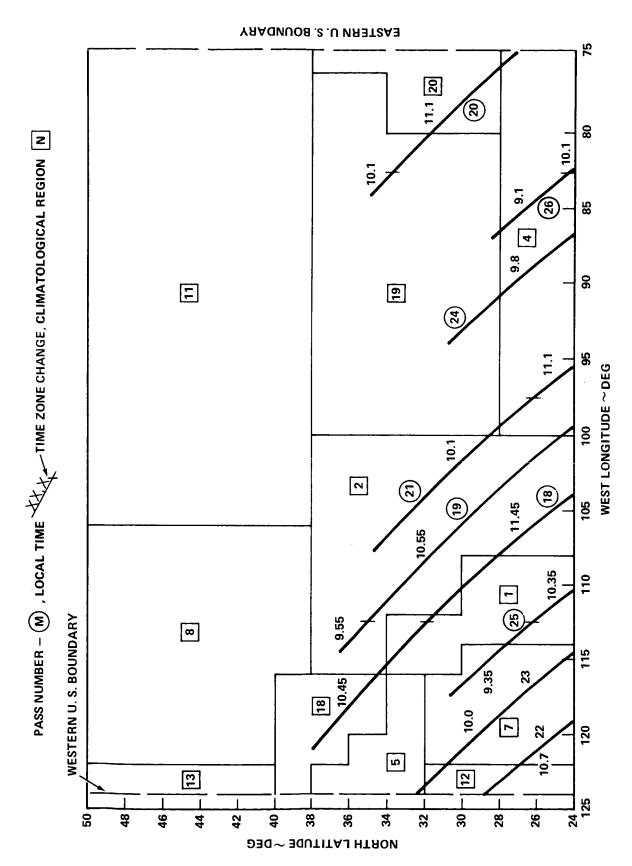


FIGURE 18 - DESCENDING PASS GROUND TRACKS, NOV. 17 -- 22 INTERVAL OF SL-4 MISSION



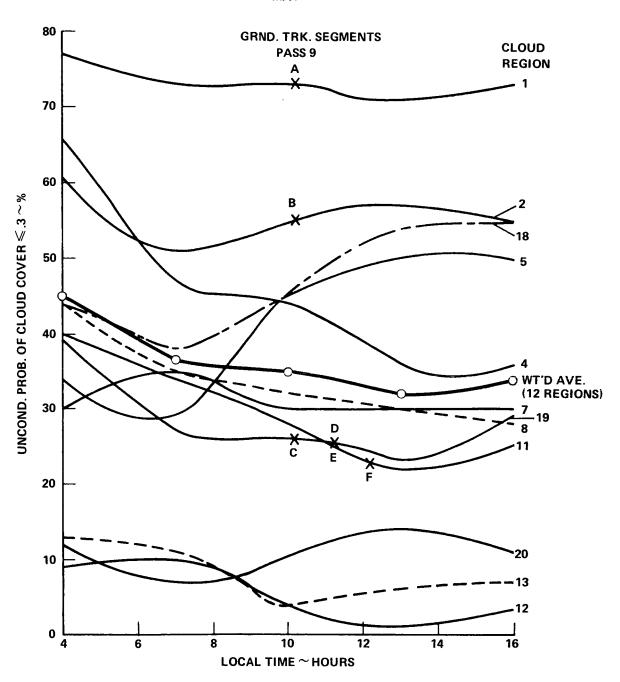


FIGURE 19 - PROBABILITY OF CLOUD COVER ≤30%

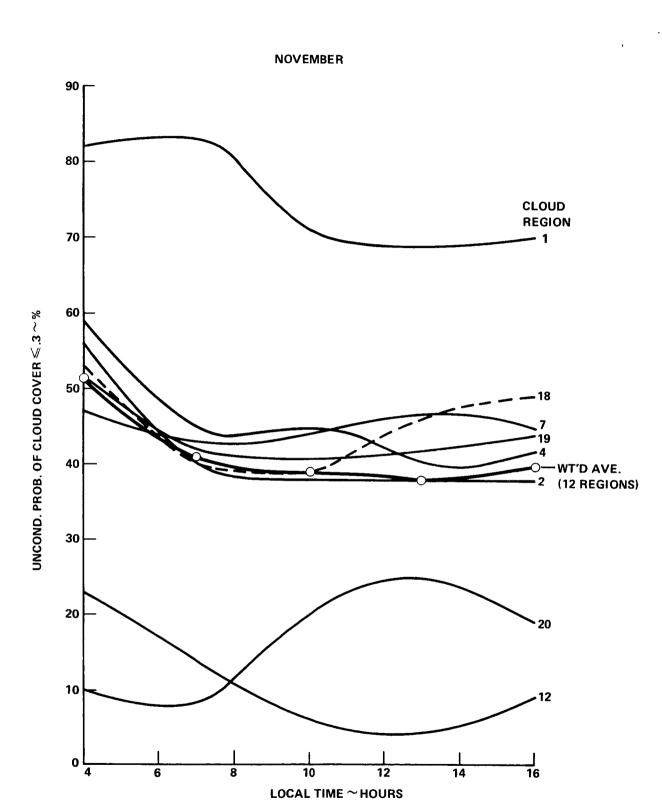


FIGURE 20 - PROBABILITY OF CLOUD COVER ≤30%



SUBJECT: April 30, 12:30 EST SL-1 Launch; U.S. EREP

Pass Characteristics and Preliminary Estimate

of Cloud Cover Effects - Case 610

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